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R.M. Poisson
D. Beevis

Defence R&D Canada

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HUMAN FACTORS ISSUES IN LAND FORCES WEAPON SYSTEMS EVALUATIONS

R.M. Poisson
D. Beevis

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
Toronto, Ontario
Canada M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE – CANADA

ABSTRACT

Human factors issues include the problems of operator performance, reliability, maintainability, availability, safety, and habitability as they relate to the interactions between the human, the machine, and the environment. Within the Canadian Forces (CF) many human factors activities are performed during the field evaluations that are conducted in support of the acquisition of weapon systems 'off the shelf.' This report is based on a review conducted in the early 1990s of some of the 'lessons learned' with regards to human factors evaluations of 'off the shelf' and prototype systems conducted for the CF. From these field evaluations it is concluded that there is a need for increased emphasis on human factors at the requirements and concept development stages of system acquisition. Due to heightened interest in Human Systems Integration issues in procurement, the original review has been revised. Conclusions are drawn and recommendations made with respect to: 1) the need to plan for human factors evaluations; 2) common design deficiencies; 3) the limitations of human factors engineering techniques and need for further research, and; 4) the need to address human factors issues in Statements of Requirements (SORs) for new systems and equipment.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Human factors in Canadian Forces Acquisition Projects

According to DND-ENG STD-3 (Ref. 1, now withdrawn), human factors covers human characteristics; it includes principles and applications of human factors engineering, personnel selection, training, life support, job performance aids, and human performance evaluation. These topics, together with health hazards and systems safety, are the subject of Human Systems Integration (HSI) programmes that are recommended for the development of complex military systems (2). Human Factors Engineering (HFE) is a subset of human factors; it includes the application of knowledge about human capabilities and their limitations to system or equipment design to achieve desired system performance requirements through the most effective use of man's performance capability. Since few military systems and equipment are developed in Canada many of the HFE activities in the Canadian Forces (CF) have been associated with Test and Evaluation (T&E) for the selection of systems or equipment.

An evaluation can be defined as:

- the study of data and information collected during a field trial;
- the reporting of the results, and ;
- development of any recommendations that the evaluator concludes is necessary improvements in the human-machine interaction (3).

In the CF, HFE evaluations are generally used either: as a development tool to redesign and improve the performance of existing systems; or as one of several factors in the selection between two. or more candidate systems; or to determine the impact of the system on the performance or health and safety of operators. To fulfill the requirements of an HFE evaluation, several specific questions must be answered:

"has it been designed and installed to facilitate operation and maintenance by the assigned personnel,
can the system function with the number and type of personnel specified, and
has the training received prepared the personnel for their roles as operators and maintainers?"

These questions are intended to link the predictions of system performance made during design with how the system actually performs when used or maintained operationally by the target personnel with the intended training (4). Design features such as displays and controls and the workspace, and variables such as operator and maintainer workload and the environment, are examined to understand the interaction between the human, the machine and the environment.

The importance of human factors evaluations is well described by the report of a Task Force on Test and Evaluation conducted by the U.S. Defense Science Board (5) which stated:

> "The task force turned up a surprisingly large amount of instances in which designs lacked adequate human factors considerations, and, notable from a T and E point of view, many in which development engineering testing did not lead to early awareness of the problem. The problems were varied: excessive sound levels, insufficient space and or inconvenient access, even poor placement of controls and read outs and most prevalent the physical work involved in the system operations were sufficient enough to double the manpower requirements for operation of some systems. Two possible solutions are: first, more attention should be given to human factors in the initial design, during modifications and updating of equipment; and second, Test and Evaluation should be planned and conducted so as to ensure that human factors requirements have been adequately considered during

design, demonstration at the first mockup of the system, and monitored through out subsequent testing."

Although test and evaluation are not the responsibility of the Defence Research and Development Branch, DCIEM staff assisted with HFE evaluations of several weapons systems in the 1970s and 1980s, prior to establishing the practice of contracting-out such work. Among weapons evaluated by DCIEM were three 155 mm towed howitzers, two anti-tank weapons, two 105 mm howitzers, three 120 mm mortars, a field ammunition re-supply vehicle and the Leopard main battle tank (6-18). A review of the results of those HFE evaluations, originally carried out in 1990 but unpublished, noted that many of the evaluations generated recommendations similar, if not identical to, recommendations made by the U.S. Defense Science Board (5). This suggested that, although each system was unique, weapons systems may suffer from generic problems in the area of human factors.

The original unpublished review of human factors evaluations conducted by DCIEM drew lessons with respect to human factors that are relevant to future acquisition projects and to the conduct of evaluation trials. In response to the growing interest in taking an integrated approach to human factors or HSI in the Department of Defence, the results of the review have been revised and the most important observations and conclusions are documented in this technical memorandum.

2. THE EVALUATIONS

The human factors evaluations performed by DCIEM staff on the twelve systems mentioned above were conducted using similar protocols. The HFE evaluations were not dedicated trials. Usually they were conducted in conjunction with other user and engineering trials scheduled for the candidate weapon systems. Typically, the trials' directive simply stated that the aim was to "assess the trial equipment from a human engineering standpoint." The directives did not attempt to link HFE issues directly to system effectiveness or to the operational requirement. Instead, system effectiveness was treated as an implicit outcome of good human factors engineering.

The US Army Test and Evaluation Command recommends that specific concerns such as user conditions, environmental conditions and operational conditions require scrutiny when conducting HFE evaluations (19). Although not based on the US test protocols, the evaluations conducted by DCIEM staff addressed the same concerns, but were more restricted in scope. The HFE evaluations were usually organized to include erectability, operability, maintainability, usability and, where relevant habitability.

Operational conditions such as threat and force characteristics, conditions of readiness, blackout conditions, logistical constraints and emergency procedures were usually addressed by other trials personnel and not by the HFE specialists. Comments were sometimes made concerning threat characteristics, but tactical exercise operations were not typically part of the HFE evaluations. Evaluations for transport, portability and maintenance were usually conducted separately from the HFE evaluations by other test and evaluation specialists.

2.1. Field Trials

Preparation for each field trial was carried out at DCIEM by first reviewing documentation available on the systems to be evaluated. Once familiar with the system documentation DCIEM staff would consult expert users, if available, to obtain information on the operation and maintenance of the system in question. This resulted in a better understanding

of the operations and drills practiced by the users or maintainers. Concurrently, a literature search was conducted to check for additional HFE trials reports pertinent to the candidate systems.

Throughout the field trials, specific drills detailing coming-into-action, operation (dry-run therefore no live ammunition) and coming-out-of-action were observed and documented to produce detailed task analyses (task analysis, rather than a static check-list of HFE design requirements, is the cornerstone to HFE evaluations). When possible, photographs and or video records were taken of each system for data analysis and reporting. Whenever possible in the field, informal interviews were used to determine the extent of any problems from the perspective of the users or maintainers. Much of the information received in this manner had to be screened for user biases and for issues not related to system design.

Physical measurements such as the torque of all hand wheels and levers, and dimensions of all portable storage boxes and tools, clearances, seat and workspace design were recorded. These observations and measurements were compiled and compared to accepted standards such as those found US Military Standard 1472 (20) and similar documents and with anthropometry data on the size range of the expected user population. Problems associated with specific environmental and protective clothing were also recorded. Biomechanical analysis was focused primarily on manual materials handling and manual control of the systems and equipment. Specific tasks were analyzed in the attempt to predict biomechanical hazards.

Once 'dry-run' training was complete, live firing followed. Live firings differed from training sessions and dry-run evaluations in that safety was paramount. The prime HFE evaluation objective was to record noise and blast measurements in order to determine the intensity of the impulse wave and establish a daily maximum exposure limit for each crew position. During these live firing trials observations such as lifting practices, colour coding of the ammunition, noise, crew protection, safety procedures and workload were also made and recorded for later discussion.

The length of the field trials usually depended on the complexity of the system, the number of users involved, the environment, the temperature and how the trials progressed. Following the trials, data collected through video, photography, or direct observations were analyzed at DCIEM to ensure that human factors engineering objectives were met by the assessment of the following (4).

1. *Design for Operation* - does the system or equipment meet human factors engineering specifications? This includes the "evaluation of the control-display relationship, visual displays, auditory displays, controls, equipment display labeling, and other factors involved in operations."

2. *Design for Maintainability* - has the equipment been adequately designed for accessibility, and quick and easy diagnosis, repair or replacement?

3. *Workspace design* - has the equipment been properly designed for the intended sequence and priority of operations? Can it be operated by the full size-range of the intended CF user population?

4. *Special tools* - is sufficient space available for storage of all required tools? Are special tools required?

5. *Communications* - can the operators and maintainers communicate so that operations and maintenance can occur in an effective and simple way?

6. *Environmental Conditions* - are the lighting, temperature, noise, vibration, and the intended method of operation and maintenance appropriate for ground conditions and any other environmental factors? Is the design suited to operation in all intended environments?

7. *Hazards and Safety* - are there any design features or conditions that present a hazard to the operators? Hs the system been designed for operation and maintenance with the anticipated protective clothing and personal equipment?

8. *Operations for Extended Periods* - can the designated personnel operate the equipment for extended periods of time?

As a final outcome to the HFE evaluations, a comprehensive report detailing the task analysis, all deficiencies and recommendations was prepared and distributed to the appropriate directorates for information and action.

3. OBSERVATIONS

Evaluations of two 105mm howitzers, three 155mm howitzers, 2 antitank weapons, three 120mm mortars, a main battle tank, and a Field Artillery Ammunition Supply Vehicle (FAASV) were carried out in the way outlined above. For the purposes of the current review the methods and resulting observations from each evaluation report (6-18) were examined. The techniques used to collect data were not standardized throughout the trials. Thus some trials may have collected observations that were not possible to make in other trials. Therefore, only limited comparisons could be made of the various observations across the twelve systems. Table 1 reports the result of a simple count of comparable observations across systems. Summary descriptions of the observations are provided in Appendix A.

The observations were grouped into five major human factors topics. The five areas where problems were common to almost all systems were: 1) inconsistent performance 2) poor workstation design, 3) ineffective or unacceptable control and display configurations, 4) high physical workloads, and 5) high impulse noise levels.

3.1. Inconsistent Performance

In each trial the crews used were not generally unfamiliar with the systems being evaluated. Typically, experienced CF operators and maintainers were selected to participate in the trials. These crews were usually chosen for their familiarity with similar equipment or because they represented the military occupational classification scheduled to operate the system if and when it came into service. The trials crews were not selected because of any special abilities or

Table 1. Summary of common problem areas identified in evaluations of 12 weapon systems.

Problem Area	Weapon System													
	105mm howitzer	105mm howitzer	155mm howitzer	155mm howitzer	155mm howitzer	120mm mortar	120mm mortar	120mm mortar	FAASV	Anti-Armor	Anti-Armor	Tank	Sum of problems	Percent cases
PERFORMANCE														
Come into action	N/O	X	N/O	X	X	X	X	X	X	N/O	N/O	N/O	7/12	58
Firing	N/O	X	N/O	X	X	X	X	X	N/O	N/O	N/O	N/O	6/12	50
Come out of action	N/O	X	N/O	X	X	X	X	X	X	N/O	N/O	N/O	7/12	58
Maintenance	N/O	N/O	N/O	N/O	X	X	X	X	N/O	N/O	N/O	N/O	4/12	33
WORKSPACE														
Sight position	X	N/O	X	X	X	N/O	N/O	X	Nil	X	X	X	8/11	73
Sight mounting	X	X	X	N/O	N/O	N/O	N/O	X	Nil	N/O	N/O	Nil	6/10	60
Inadequate workstation	X	N/O	X	X	X	X	X	X	X	X	X	X	11/12	92
Handhold location	X	X	X	N/O	X	N/O	N/O	N/O	N/O	N/O	N/O	X	5/12	42
Clothing interaction	X	X	X	X	X	X	X	X	X	X	X	X	12/12	100
Stowage	N/O	N/O	N/O	N/O	X	X	X	X	X	N/O	N/O	X	6/12	50
Snow and mud	X	X	X	N/O	X	X	X	N/O	N/O	N/O	N/O	X	7/12	58
CONTROLS & DISPLAYS														
Poor control location	X	X	X	X	X	X	X	X	X	X	X	X	12/12	100
Hand crank design	N/O	N/O	N/O	X	N/O	N/O	N/O	N/O	Nil	Nil	Nil	N/O	1/9	11
Elevating & traverse	X	N/O	X	X	X	N/O	X	X	Nil	Nil	Nil	X	7/9	78
Control clearance	X	X	X	X	X	N/O	X	X	X	N/O	N/O	N/O	8/12	67
WORKLOAD														
Physical workload	X	X	X	X	X	X	X	X	X	X	X	N/O	11/12	92
Training problems	N/O	X	X	N/O	X	X	X	X	N/O	N/O	N/O	N/O	6/12	50
High angle loading	X	X	X	N/O	X	X	X	X	Nil	N/O	N/O	N/O	7/11	64
NOISE														
High impulse noise	X	X	X	X	X	X	X	X	Nil	X	X	X	11/11	100
Communication problems	N/O	N/O	N/O	N/O	X	X	X	X	X	N/O	N/O	X	6/12	50

training. In many cases insufficient time was scheduled for these personnel to train and establish repeatable Standard Operating Procedures (SOPs) for the systems being evaluated.

Since the trial crews lacked adequate training and established SOPs, task sequences, task times, come-into and come-out-of action times were rarely consistent from repetition to repetition. Whereas it should be expected that performance times would improve during the trials, this was seldom the case. As the trials progressed the operators changed and modified the operating procedures as a result of their experience. Not until all SOPs were firmly entrenched in the operators' minds and routinely implemented were improvements in task times recorded.

In a few trials the human factors evaluations were conducted at the very end of the user trials. By that time techniques and SOPs had been established. As a result, the performance times were more consistent and there were clear distinctions between candidate systems.

3.2 Workspace

Workstation design issues include the operator's safety, ease of access to controls and displays, accessibility (ingress and egress), general functionality of the equipment and operator comfort. As shown in Table 1, problems with inadequate workstation design were identified in almost all of the evaluations. In many cases it appeared that little or no regard had been given to the operators or maintainers when the systems or equipment were designed. Controls and displays were placed more out of engineering convenience than operator necessity. In most systems, comfort was non-existent.

With four of the systems the position of the sight made it difficult to lay the weapon because the operator could not view through the site while simultaneously adjusting the traverse or elevation. In several cases there were problems not only in using the sights but also with their mounting, storing, and night use.

On one 155 mm. howitzer the workspace layout was extremely poor. Accessibility was limited; for laying the weapon a crewmember had to mount the left trail without any steps or handles, and, once in position, was forced to sit directly on the hard cold metal surface of the trail directly on top of a hand pump for a hydraulic jack. The awkward body posture required restricted the operator so that only the elevation hand-wheel was within reach. To operate the traverse hand-wheel the operator had to climb up over the left wheel, alternating adjustments in elevation and traverse.

Workspace was also poor on the Field Artillery Ammunition Supply Vehicle (FAASV). The space available to the crew while in transit was inadequate. The seat and seating arrangements were less then satisfactory, the amount of space was extremely limited and a number of obstacles projected hazardously into the seating area.

The design of several of the systems made make it difficult, although not impossible, to operate them in environmental clothing. Crews often displayed frustration while working in environmental clothing. More importantly, their ability to manipulate fine controls was impaired forcing them to remove their arctic or CD mitts or gloves, thereby putting them at risk. Such observations were not unique or isolated events. For example, gunners removed their CD gloves to perform simple tasks including adjusting camouflage netting. Such 'work-arounds' resulted in the satisfactory 'evaluation' of equipment that, in a real CD threat scenario would not be usable.

If handholds were provided, they were seldom designed with environmental clothing in mind, nor were they designed to accommodate heavy lifts. In many cases the handholds could not be used with mitts. Generally handholds were positioned for convenience of manufacture and forced the operators to adopt awkward postures to use them. Frequently the diameters of the

handholds were too small for the weight to be lifted and heavy objects that required a two-handed lift had handholds designed for one hand

Insufficient personal equipment storage was a problem with several of the systems. The crews' personal kit appears to be neglected in the design of weapon systems. The lack of storage for personal kit varied from inconvenient to dangerous. On the FAASV the crew used any available free space to store their kit. They used the flash sensor (a device which senses any bright flash such as an explosion, and triggers a fire suppression system) to hang their parkas, effectively rendering it useless. The crew also packed the rest of their kit in and around the release valve of the Halon canister affecting the effectiveness of the fire suppression system. Even had the flash sensor detected a fire, the release of Halon would have been impeded (16).

Most trials included winter conditions when snow and mud continually hampered crew performance by caking on controls, displays and many critical moving parts. In harsh winter conditions a large proportion of time coming-into and out-of-action (except for sighting in some cases) was spent clearing the systems of ice and snow. Some problems were avoided by covering the gear-boxes where accumulations of mud and ice could collect. However, design is a superior preventative. For example, during one trial snow compacted in a socket intended to secure a spade for a crew-served weapon and precious time was spent scraping the snow out from the hole. Simple re-design would have made it easier to clean the socket by allowing the snow to be pushed through the socket.

3.3. Controls and Displays

Problems associated with controls were identified in all twelve systems. Ten had poorly located controls that provided inadequate clearance. On one weapon a hand-wheel was so close to the sight mount that the operators would frequently skin their knuckles on the sight. Other controls were confusing to operate. On one weapon the traverse hand-wheel rotated forward and backward while the elevation hand-wheel rotated left and right. Such a reversal of the expected movement of the elevation and traverse hand-wheels encouraged crew to make mistakes when laying the weapon.

Virtually none of the hand-wheels on the various systems met the appropriate human factors engineering design standards. In most cases the diameters of the hand-wheels were inadequate for the torque that had to be exerted. In addition the combination of torque and hand-wheel movement was inefficient; either the torque was too high and the revolutions required too low, or the torque too low and the number of revolutions required too high. One 120 mm mortar system had a powered traverse and elevation mechanism which was controlled by a central joystick. The joystick did not permit fine control, making it extremely difficult to make accurate laying adjustments. In addition, as the barrel passed its centre of rotation it would jerk away from the centreline under its own weight. This problem was compounded because of the sensitivity of the sight bubbles that tended to move very quickly (13). Laying this system was frustrating for the crew and could never be accomplished in the allotted time.

Few of the systems relied on advanced display technology and, in general, there were few problems with displays except for the sights (the position of the periscopes in the Leopard task was a problem for the intended user size-range). The sights were the primary displays on the weapons and in almost all evaluations the sights used in the trials were not compatible with many items of CF personal equipment such as helmets, glasses, CD gear and arctic clothing. Although detrimental to the proper operation of the systems, this observation was usually set aside because

the sights were to be Government Furnished Equipment (GFE). Incompatibilities associated with current CF sights are widespread and not limited to the trials reviewed in this report.

3.4. Workload

Mental workload was not identified as a problem in any of the evaluations reviewed. Conversely, physiological workload was a consistent problem. Handling the weight and size of system components (ammunition, weapons howitzer trails, baseplates etc.) limited system effectiveness and put the operators at risk more frequently than any hazard other than possibly excessive noise (6-12,14-17). Current crew-served weapon systems can require ammunition rounds to be man-handled up to 6 times, not always by the same individual. Only when ammunition was kept palletized until it reached the weapon was handling of ammunition kept to a minimum. This was usually the exception. Excessive handling occurred when the pallets of ammunition were broken down before they were sent to the field. This happened regularly during the trials because the restricted quantities of ammunition allotted to the trial was not enough to fill an entire pallet, or if they did, lifting equipment for the pallets was unavailable.

During trials, crew consistently denied that excessive lift weights and high lift frequencies affected their performance. However, as the trials progressed the physical stress became more apparent as the crew's performance deteriorated. Usually towards the end of prolonged trials individuals were more willing to agree that fatigue had some affect on their performance.

Although crews sustained numerous cuts, scrapes, and even one broken finger as a direct result of manual handling of the systems, the greatest single source of injuries was excessive physical exertion. In a number of trials, lifting tasks were assessed with the National Institute of Occupational Safety and Health (NIOSH) lifting model (21). Operators were frequently required to lift objects, some in excess of 40 kg, that were well above recommended NIOSH limits.[1] For example, the crew of a 155 mm howitzer can be required to maintain a sustained (high) rate of fire of approximately three rounds per minute indefinitely. Such a rate places the ammunition handling tasks in the upper zones of the NIOSH risk categories where injuries must be expected. Considering the high weight of equipment and ammunition compounded with a high lift frequency, fatigue, and cold, injury rates during some trials were predictable (17). During one 155 mm. howitzer evaluation it was deduced that any crew member had a 60-99 % chance of sustaining an injury as a direct consequence of manual materials handling (MMH). As predicted, after the first day, while helping lift a trail, a crew member had to be replaced due to lower back injury (8).

In many cases the highest risk was of back injury. This risk of injury was amplified by high angles of fire with some weapons. Crews would either: dig a pit under the breech, forcing loaders to bend their trunk excessively in order to load the round into the breech, or; they would reduce the elevation each time to load, which substantially impaired performance times.

Such problems are a function of the size and weight of the ammunition and of individual components of each weapon. They also highlight problems with design for handling. Users were frequently required to lift items that put them at risk because of the awkward body position the operator was forced to assume as a result of poor design. On occasion an entire crew was put at risk because they were all required to make heavy lifts in unison, for example opening or closing

[1] NIOSH recognizes 3 lift zones, 1) safe for the majority of the population, 2) requires administrative changes such as training, or the lift is only safe for a limited population, and 3) requires engineering changes or the lift is unsafe for the entire population.

the trails of a howitzer in the snow. If one person should fail the probability of others sustaining injuries was enhanced as in a domino effect

3.5. Noise

Another serious health hazard was associated with the various systems was the extremely high noise levels common in weapons of these calibres. The most significant effects of noise and blast are masking of speech and warning signals, annoyance, temporary or permanent hearing loss, and in severe cases, damage to the air filled cavities of the body (22).

Many of the systems evaluated had noise levels well beyond the pain threshold. One system had a maximum recording of 196 decibels at a particular crew position. Levels beyond 190 decibels can result in epidemiological complications. In fact it was not uncommon to calculate maximum daily exposure limits of zero rounds per day for the higher charges.

Surprisingly, during live firing crew and DND observers around the system often wore their personal hearing protection incorrectly or not at all. This suggests that either they had not been instructed how to wear the protection correctly or they chose to wear it incorrectly because they are oblivious to the consequences of their actions.

4. DISCUSSION

Although many of the HFE observations were subjective in nature and some of the performance data had to be extrapolated, the information summarized from the twelve reports can be treated with confidence. The majority of observations were not reported unless they occurred on a number of occasions, i.e., they were repeatable observations within a specific trial. It also appears reasonable to assume that the interpretation of the human factors data from video or photo and audio analysis was reliable.

Caution must be exercised in making comparisons across all twelve of the trials reviewed in this report. Some of the earlier trials were directed at developing improved hardware and were usually an intermediate step in the acquisition process. In later trials, the human factors specialists were given more flexibility to modify prototypes to reduce the physical workload and enhance performance through minor design changes. Because of these differences the comparison of observations was limited to the compilation shown in Table 1 based on the observations summarized in Appendix A.

The comparison of observations suggests that few of the evaluation trials would have provided positive answers to the three questions posed in the Introduction: "has it been designed and installed to facilitate operation and maintenance by the assigned personnel, can the system function with the number and type of personnel specified, and has the training received prepared the personnel for their roles as operators and maintainers?" Five problem areas appear common across a variety of weapon systems, whether new or modified:

- inconsistent performance measures
- ineffective workspace design,
- poor control and display design,
- excessive physical workload, and,
- noise hazard to hearing.

4.1 Inconsistent Performance Measures

Performance measures were a concern in several of the trials. Usually, performance with a crew-served system increases with training until a plateau is attained. When the operators are

familiar with a crew-served weapon system and have with established SOPs, performance times can be expected to conform to a learning curve similar to the one shown in Figure 1 (23). The advantage of this is that the final plateau of performance can be predicted from three observations early on in the trials. If SOPs are changed then performance does not improve in a consistent manner and the plateau of performance is impossible to predict (Figure 1: Underdeveloped SOPs). In such a case it is possible that the performance measurements could result in the selection from among several candidates of a system that is not the most effective.

- 10 -

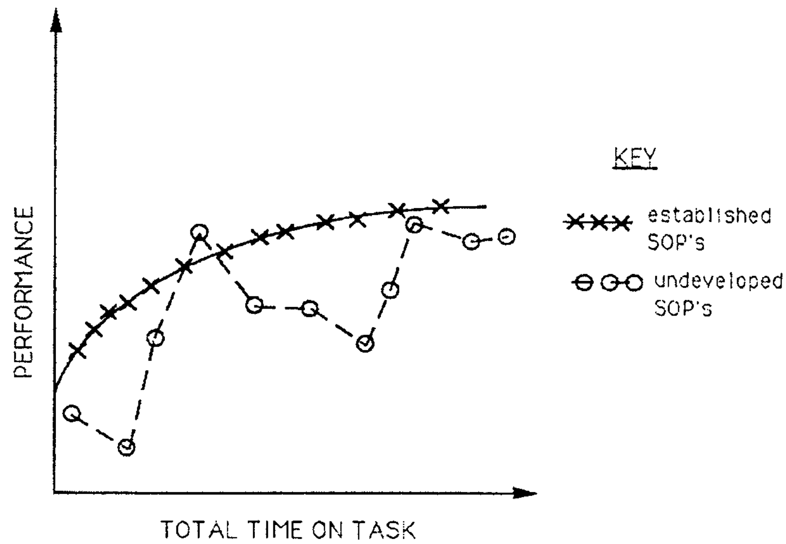

Figure 1. Learning curves of trained and untrained individuals (simulated).

In virtually all cases during CF user and engineering trials insufficient time was allotted to establish SOPs which could be used to train the trials crews adequately. Typically a new or modified system would be in the hands of the user group only one or two weeks prior to an HFE evaluation, sometimes due to a shortage in manpower or a shortage in funds. Because of these limitations the trials were conducted at the same time that the SOP's were being established and troop training was being conducted. In later trials the human factors evaluations were conducted after the user and engineering trials were completed, thus giving the crew some limited additional training. One lesson here is that sufficient time must be budgeted to allow for the establishment of CF SOPs for new systems and equipment. The US Task Force on Test & Evaluation made similar observations about inadequate early planning for evaluation (5). Another lesson is that performance measures should be scheduled only after SOPs are established, the trials troops trained, and consistent performance measures are achieved.

In several cases the trials troops were selected for their availability or experience rather than the extent to which they represented potential users. This brings into question whether such trials adequately addressed the suitability of candidate weapon systems for operation and maintenance by the intended personnel. In no case was a training package from the weapon system supplier used to train the trials crews. Thus the evaluations did not address whether training packages that could be purchased with such systems might be adequate for the CF. The new DND SOR templates include Training as a topic.

4.2 Ineffective Workspace Design

It is apparent from the evaluations conducted by DCIEM, and from those reported by other organizations, that the application of HFE has not been a priority in the design or development of many weapon systems. The US Task Force on Test & Evaluation made many observations similar to those reviewed in this report (5). The Task Force identified problems including: a lack of storage space, inadequate heating and lighting, sharp obstacles which could injure or damage environmental clothing and, simply a basic inability to operate in the anticipated operational environments. Given their similarity to US findings, the observations reviewed in this report appear to be generic deficiencies. The templates for Statements of Requirements introduced by the Directorate of Business Change Management in 1999 include Deficiencies, and those noted in this report, or in the specific weapon system evaluation reports (6-18), could be included in the SORs for new systems.

This review has shown that bidders do not always anticipate the unique aspects of CF operations, the full range of body sizes and gender mix of CF personnel or the environmental clothing and equipment used by the CF. In every case systems had not been designed to accommodate personal clothing and equipment above and beyond standard summer clothing. Canadian winter conditions pose the most severe restrictions on both the crew and weapon system. During cold weather trials the compatibility between the operators' clothing, the weapon system and the working environment is critical. For that reason DCIEM contracted a study to document the size increments associated with land forces environmental clothing and the new Improved Environmental Clothing System (IECS) (24). Requirements for future systems must include operations under the possible threat of chemical or biological warfare and the realities of the Canadian environment. A much more concerted effort should be made to specify and to design systems which resist impairment from snow or mud being compacted on or in critical parts of the mechanism.

These workspace design deficiencies emphasise the importance of providing, in any future SORs, the concept of operations and maintenance and the expected operating environment, as well as information about personnel characteristics and environmental clothing. The new DND templates for SORs (25) cover these topics under the headings: Missions and Scenarios, Key Roles, Key Tasks; User Characteristics; Crew Station and Interface Design; User Acceptance; Operability; Survivability; Maintainability; Safety and Health; Personnel and Training Requirements[2], and examples of typical entries are given in Table 2.

4.3 Poor Control and Display Design

As shown in Table 1, the most common deficiency under this heading was poor control location. Ineffective design of elevation and traverse controls was observed with crew-served weapons and clearance around controls was also a problem in the majority of systems evaluated. This neglect can have significant repercussions:

> "The effect of the man on the machine will have significant impact on system performance in terms of target acquisition and destruction. The machine and

[2] It was to provide information on infantry operations that DCIEM had the 'Soldier's Day' CD-ROM developed for Directorate of Land Requirements (26) containing information on the organizations, tasks and equipment used by the infantry.

environmental effects on the man will significantly impact system safety and reliability, particularly in terms of the man's contribution to system performance" (27).

The US Task Force (5) emphasized that a lack of reliability was demonstrated not only by "random failures of components but also by failures induced by poor hardware design, poor software design, operator errors, wear out, and failure to appreciate the severity of environmental conditions." The Task Force pointed out that the failures meant that forecasts of system reliability were unrealistic because reliability goals could not be met (reliability was defined as the probability of completing a mission of specific duration). They argued that testing should adequately demonstrate that the achievement of system performance goals could be accomplished successfully and that the performance of the crew and maintainers should be included in any measures of systems effectiveness or performance requirements.

The new DND SOR templates introduced in 1999 include Performance Measures as a topic. In addition, an acceptable standard of human factors engineering (for, example, US MIL-STD-1472) should be required in new SORs under the heading of Crew Station and Interface Design, as well as compatibility with CF protective clothing and personal equipment, under the headings shown in Table 2.

4.4 Excessive Physical Workload

As shown in Table 1, most of the systems evaluated had problems associated with manual materials handling. Administrative changes such as training would have little if no effect on these problems because of the severity of the physical workload demands. In several trials it was found that the crew could not maintain the rates of fire advertised for a particular weapon because of the excessive physical workload. This has implications for Operational Analysis studies which often use manufacturer's data to compare the effectiveness of different weapons.

Table 2: HFE issues that should be addressed in SORs for new systems

SOR TEMPLATE HEADING	REQUIREMENT DERIVED FROM LESSONS LEARNED
Missions and Scenarios:	▪ Outline concept of operations ▪ Full range of anticipated environmental conditions (day, night, all weather, NBCD etc.)
Key Roles, Key Tasks:	▪ Reference to CF SOPs that will affect use, resupply or maintenance of the system
User Characteristics:	▪ Full range of body sizes ▪ Gender mix of intended users ▪ Handedness ▪ Corrected vision
Crew Station and Interface Design	▪ Compatibility with protective equipment such as ballistic visors, NBCD respirators and gloves, and CF helmets ▪ GFE such as weapons sights ▪ Design according to an acceptable standard of HFE , for example, US MIL-STD-1472

User Acceptance:	▪ Requirements for stowage of personal gear ▪ Crew comfort
Operability:	▪ The environmental clothing and equipment used by the CF ▪ Subjective measures of operability
Maintainability:	▪ Concept of maintenance including resupply
Safety and Health:	▪ The need for the intended CF operators and maintainers to be able to carry out their tasks without risk of injury due to over-exertion ▪ The need to fire the specified number of rounds per day from a weapon system without hazarding crewmembers hearing when wearing CF issued hearing protection ▪ The need for the design to minimize risk of injury or hazard to crew members
Performance Measures:	▪ Inclusion of HF measures in system effectiveness, availability and reliability (measures to be used with the crew 'in the loop') ▪ The conditions of measurement, e.g. crew trained to a plateau, rates of fire to be sustained for X hours by the same crew
Personnel and Training Requirements:	▪ Constraints on the number and types of personnel available ▪ Constraints on training, e.g., time available, staffing for training

The high probability of crewmembers sustaining an injury as a direct result of the physical workload should be a major concern with new systems and equipment. To reduce the physical effort associated with the handling of the ammunition and the excessive weights of some of the components on some current systems, the height of the lift or the weight or the frequency of the lift would have to be reduced. It is doubtful that the weights of the ammunition or individual system components will change in the near future, therefore engineering solutions such as reduced lifting heights or automated lifting aids are required. For yet to-be-developed systems a change in design philosophy is highly recommended.

For evaluation trials, one precaution with regards to handling of the ammunition would be to have personnel other than the trials crew handle the ammunition before it arrives at the gun emplacement. To avoid over-exertion problems, individuals other than the trial crew should perform any labour or work that is not directly related to the trials or the operation of the weapon. Although this does not represent operational reality it reduces the potential for injury among the pool of trained trials crew.

The analysis of potential lifting hazards is a relatively untried tool in the HFE evaluations. In several of the trials, lift characteristics such as load weight, lift distances and frequency were used to run the National Institute of Occupational Safety and Health (NIOSH) lifting model (21). While this was a simple procedure, a major limitation was that NIOSH is based on static lifts using two hands in the sagittal plane. Therefore, the applicability of results from field analysis was relatively limited. In addition, some recent research has brought the sensitivity of the NIOSH model into question.

Another model, developed at the University of Waterloo (WATBAK) was used by DCIEM in later trials. This is a more complex lifting model that can be used to determine postural limits for asymmetric lifting and pulling and is able to calculate lifts outside the capabilities of NIOSH. WATBAK appears to be more flexible than the NIOSH model, however it requires data from a number of points on the human body which cannot be tracked through heavy clothing. This reduces the effectiveness of the model for field evaluations and the lifting tasks must be simulated in the laboratory using subjects wearing light clothing. Although this observation was originally made some years ago, there appears to have been littly progress in developing lifting models that can be applied in the field. Additional research is required on these lifting models. From the procurement perspective, SORs should emphasize the need for the intended CF operators and maintainers to be able to carry out their tasks without risk of injury due to over-exertion. With the new DND SOR templates his can be done under the heading of Safety and Health.

4.5 Noise Hazard

The common observation of the noise hazard associated with new weapons was also reported by the US T&E Task Force (5). With respect to administrative procedures, it is the responsibility of all those involved in evaluation trials to ensure that crew are adequately protected and that the protective equipment is properly used. This means that restrictions must be placed on the number of exposures per day, even if it is at the expense of performance and training. With respect to procurement, the SOR should address the need to fire the specified number of rounds per day from a new weapon system without hazarding the hearing of crew members when they are wearing CF issued hearing protection. Again, with the DND SOR templates this can be done under the heading of Safety and Health and cross-referenced to Operability. Several other Human Systems Integration requirements should be addressed in the SORs, using the headings shown in Table 2.

5. CONCLUSIONS AND RECOMMENDATIONS

Several general conclusions can be drawn with respect to the generic human factors problems identified in this review. The conclusions are related to: common design deficiencies; the need to plan for human factors evaluations; the limitations of human factors engineering techniques and need for further research, and; the need to address human factors issues in Statements of Requirements (SORs) for new systems and equipment.

5.1 Planning for HFE Evaluations

Wherever possible, greater emphasis should be given to HFE aspects of evaluation trials. A desirable extension of current practice would be to use mock training exercises with a simulated enemy.

It is essential that SOP's be established and practiced until performance plateaus, and that the crew adhere to those SOP's during the trial. Sufficient resources and trials time must be budgeted to allow for the establishment of CF SOPs for new systems and equipment. Crews must be assigned for the full duration of the trial.

To reduce the possibility of injury, crews should be given pre-trials training on:

- how to lift properly,
- hearing protection and how to use it,
- potential health hazards associated with the system.

Trials administration personnel must ensure that maximum health hazard exposure limits are strictly adhered to. Everyone involved in weapons trials must use appropriate hearing protection whether it be ear-muffs, ear-plugs or both.

If possible, other personnel should be assigned to perform manual materials handling tasks associated with maintenance or re-supply to avoid over-exertion of the trials crew, especially during sustained firing trials.

5.2 Common Design Deficiencies

Four common design deficiencies were observed:

- poor or inadequate workspace design,
- ineffective control and display design,
- excessive manual-materials handling workload,
- hazardous levels of noise.

Such deficiencies bring into question any forecasts of system reliability based on engineering criteria alone, because reliability goals cannot be met if HFE deficiencies limit system performance.

5.3 The Limitations of HFE Techniques and Need for Further Research

There is need for further research into human lifting models and methods for evaluating manual material handling tasks in the field.

5.4 The Need to Address HFE Issues in Statements of Requirements (SORs)

A concept of operations and maintenance, and information about the expected operating environment, personnel characteristics and environmental clothing are essential components of the SOR for new systems and equipment. As shown in Table 2, these requirements can be addressed under the headings of the new DND SOR templates.

6. REFERENCES

1. DND (1969). *Definitions of Systems Effectiveness Terms For Reliability, Maintainability, Human Factors And Safety.* DND-ENG STD-3, Ottawa: Department of National Defence.
2. Research Study Group 21 (1994). *Liveware Integration: Final report.* AC/243(Panel 8)TR/18. Brussels: NATO Defence Research Group Panel 8.
3. USAF (1966). *Handbook of Instructions For Aerospace Personnel Subsystems Design (HIAPSD).* Air Force Systems Command, Andrews AFB, USA.
4. Long, J. L. (1970). *Weapon Systems Personnel Requirements Evaluation Techniques.* WRM 70-40.
5. US DSB (1974). *Report Of Task Force On Test And Evaluation.* Washington D.C.: US Defense Science Board.
6. Rowe, K., M. Hill, R. Angus, S. Forshaw and B. Crabtree. (1977). *Human Engineering Evaluation of XM 198 155-MM, Towed Howitzer.* Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
7. Hill, C. M. (1979). *Human Engineering Report of FH 70 155-MM, Towed Medium Howitzer.* Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.

8. Nottrodt, J. W. and R. M. Poisson. (1985). *Human Engineering Evaluation of the M114/39 155 MM Towed Howitzer: Preliminary Report.* Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
9. Rowe K., Hill, M., Angus, R., Forshaw, S. and Crabtree, B. (1977). ***Human** Engineering Evaluation of XM 204, Soft Recoil, 105-MM, Light Howitzer.* Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
10. Rowe K., Hill, M., Angus, R., Forshaw, S. and Crabtree, B. (1977). *Human Engineering Evaluation of L118, 105mm, Light Gun.* Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
11. Nottrodt, J. W., D. Beevis and R. M. Poisson. (1984). *Human Engineering Evaluation of the Brandt RT 61 120 MM Mortar.* Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
12. Poisson, R. M., D. Beevis and J. W. Nottrodt. (1984). *Human Engineering Evaluation of the Tampella A4 120 MM Mortar.* Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
13. HS Inc. (1989). *Assessment of Effects on Military Equipment Performance on An Auxiliary Power Unit M114/39 155MM Howitzer.* HSI Project No. 2130, Contract No. OISE.W7711-8-7054. Report. Guelph, Ontario: Human Systems Inc.
14. Sutton, K. M. (1986). *Human Engineering Evaluation of Short Range Anti-Armour Weapons (SRAAW).* HF 86/13, Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
15. Poisson, R. M. (1984). *Prototype 84 mm LRG Human Engineering Recommendations.* 3615D-1 (Beh), Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
16. Poisson, R. M. (1986). *Field Artillery Ammunition Resupply Vehicle Human Engineering Recommendations.* 3615A - 1 (HF), Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
17. Hill, M. W. (1983). *Human Engineering Evaluation of the Leopard C1 Main Battle Tank.* DCIEM Report No. 83-R-15, Toronto, Ontario: Defence and Civil Institute of Environmental Medicine.
18. HumanSystems Inc. (1990). *Human Factors Evaluation of NORICUM SM-4 Mortar System on an M113A2 Armoured Personnel Carrier.* HSI Project No. 2192, Contract No. W7711-9-7073/01-XSE report. Guelph, Ontario, Human Systems Inc..
19. (1981). *Work Practices Guide for Manual Lifting.* Cincinatti: National Institute for Occupational Safety and Health.
20. Perkins, J. C., D., Benel C.R. and Avery, L.W., (1983). *Human Factors Engineering Part 1 Test Procedures* (U) TOP 1-2-610. ESSEX Corporation.
21. *Human Engineering Design for Military Systems, Equipment and Facilities.* MIL-STD-1472 . Washington, D.C.: US Department of Defense.
22. (1975). *Human Factors Engineering Design For Army Material.* MIL-HDBK-759, Washington D.C.: US Department of Defense.
23. Towill, D.R. (1989). Selecting learning curve models for human operator performance. In, G. McMillan, D. Beevis, E. Salas, M. Strub, R. Sutton, and L. van Breda. Applications of human performance models to system design. New York: Plenum Press.
24. Carrier, R. and Meunier, P. (1996). Effects of environmental clothing on anthropometric measurements and functional limitations. DCIEM-96-CR-22. Montreal, QC: Les Consultants Genicom Inc.

25. DND (1998). *Guidelines on the Preparation of a Statement of Operational Requirement.* Ottawa, ON: Department of National Defence. (Available through ADM(Mat) web site on the DND Intranet (DIN), under "What's New")

26. Kumagai, J.K. and Tack, D.W. (1998). Soldier's Day population of reference material: Final report. DCIEM 98-CR-35. Guelph, ON: HumanSystems Inc.

27. Brooks, W. E. (1978). *Methodology Investigation Requirements for the Test and Evaluation of Direct-Fire-Anti-Armor Weapon Systems.* 7-CO-RD6-YP1-007, Aberdeen, MA: U.S. Army Test and Evaluation Command.

APPENDIX A: DETAILS OF HUMAN FACTORS PROBLEMS OBSERVED IN FIELD TRIALS AND EVALUATIONS OF 12 WEAPON SYSTEMS

A1. L118 105 mm Light Gun

- trials troops inexperienced on system
- improper handles on platform increase physical workload
- lack of handles on trails makes it difficult to hook and unhook from prime mover
- handles have an inadequate clearance
- difficult to position on icy terrain
- increased workload as a result of high angle firing
- high impulse noise.

A2. XM 264 105 mm Light Howitzer

- wheel raising hand-wheel is poorly located
- elevation and traverse hand-wheel poorly located
- difficult to mount sights and incompatible with environmental clothing
- lack of sufficient handholds on the muzzle increases the physical workload required to engage and disengage the weapon from the prime mover
- potential back strain when disengaging from prime mover
- difficulty moving weapon in snow
- lifting handles on trails not long enough
- high impulse noise

A3. FH 70 155 mm Howitzer

- safety knob on the re-cocking handle is too small.
- APU controls are poorly designed.
- hand-wheel too close to the seat location
- hand-wheel difficult to operate in arctic clothing
- hand-wheel will spring out of control if barrel depresses under it's own weight
- sight is poorly located and is awkward to use in arctic clothing
- shorter members have difficulties pushing the rammer fully forward to the breach
- at the lower charges rammers did not function properly therefore the rounds had to be rammed by hand
- unfolding the weapon is potentially hazardous - barrel can swing out of control if crew members do not maintain control of the ropes at all times
- increased workload if auxiliary power unit fails
- extremely high noise and blast overpressures.

A4. XM 198 155 mm towed howitzer

- trials troops inexperienced on system
- it is difficult to turn the elevating, depressing hand-wheel, and clutch - process is labour intensive - takes up to three men
- loading weapon at higher elevations is difficult.
- lack of proper handholds on trails for lowering and lifting.
- it can take up to eight men to close the trails.
- potential for back strain when lowering trails

- spades are very heavy - mounting spades is difficult
- snow & mud clogged the trail slot on the spade..
- the poor design of the loading procedures and equipment substantially increases the physical workload.

A5. 114/39 155 mm Towed Howitzer

- trials troops inexperienced on system
- lack of suitable workspace for the #3 crewman
- poorly located controls (traverse, elevation handwheels, and sight)
- incompatibility with CF environmental clothing
- snow will accumulate in the holes where the securing spike for the spades is located thus increasing performance times
- poorly designed and oriented spade handles
- manual materials handling problems associated with ammunition and weapon components (trails, spades, baseplate, etc)
- it requires 10 individuals to attach the weapon to its prime mover (MMH intensive)
- high impulse noise.

A6. Tampella A4 120 mm Mortar

- trials troops inexperienced on system
- design of the barrel-screw clamp is not suitable for fast and easy operation
- the handles on the screw clamp are not compatible with environmental clothing
- the handles have an inadequate clearance
- inadequate clearance on the elevation hand-wheel
- controls are out of reach at higher firing elevations
- high reach to load the barrel, loader must stand on something to reach the end of the barrel.
- individuals can catch their fingers between the leg of the bipod and the centre of the elevation jack
- manual material handling problems associated with some aspects of the weapon are extreme
- excessive noise and blast overpressure.

A7. Brandt RT 61 120 mm Mortar

- elevation wheel lock is too close to the elevation hand-wheel
- lack of storage for clamp and towing eye
- loader had to stand on something to load the barrel
- some risk involved in manual materials handling of ammunition
- ice and mud can collect inside the barrel clamp
- mud and ice picked up by the towing eye could contaminate the barrel
- high noise and blast overpressure.

A8. NORICUM SM.IP -4 120 mm Mortar System

- controls and displays not well organized.
- poor control co-ordination.
- poor sensitivity of controls.

- sighting the weapons took up to 50% of the time
- incompatibility with CF environmental clothing.
- definite manual materials handling problem with the ammunition.
- poor design of the barrel loading indicators
- inadequate storage.
- high impulse noise.

A9. Field Artillery Ammunition Supply Vehicle (FAASV)

- X-Y stacker control switches are poorly located
- poor hand clearance between the locking handle and top of the track for the X-Y stacker
- inadequate design of the X-Y stacker controls, require a foot brake to stop the stacker from sliding on steep grades
- stacker tray requires a knob assembly which would lock the sliding tray into set positions
- on-off switch for conveyer poorly located
- controls incompatible with environmental clothing
- seating dimensions not according to standards
- seating arrangement for crew inadequate
- solenoid switches could not be depressed with a finger, crew resorted to using any tools which would fit the slot
- APU control box poorly located
- difficult to ingress and egress
- hazardous intrusions into the crew spaces (potential for tearing environmental clothing and/or injuring crew)
- awkward workspace
- centre overhead door far exceeds weight limits

A10. Carl Gustav Anti-Armour Weapon

- difficult to cock
- off balance when used with 132mm round
- incompatible with environmental clothing
- high weight of system makes system workload intensive
- high impulse noise.

A11. LRG (Light Recoiless Gun) Anti-Armour Weapon

- difficult to cock.
- off balance with 132mm round.
- incompatible with environmental clothing.
- high impulse noise.

A12. Leopard C1 Main Battle Tank

- layout of displays is generally poor, especially for the driver
- drivers seat offers poor range of adjustability
- insufficient workspace for gunner
- incompatibility with environmental clothing

- lack of proper handholds on the outside of the tank
- insufficient storage space for personnel effects
- high impulse noise.

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Human factors issues include the problems of operator performance, reliability, maintainability, availability, safety, and habitability as they relate to the interactions between the human, the machine, and the environment. Within the Canadian Forces (CF) many human factors activities are performed during the field evaluations that are conducted in support of the acquisition of weapon systems 'off the shelf.' This report is based on a review conducted in the early 1990s of some of the 'lessons learned' with regards to human factors evaluations of 'off the shelf' and prototype systems conducted for the CF. From these field evaluations it is concluded that there is a need for increased emphasis on human factors at the requirements and concept development stages of system acquisition. Due to heightened interest in Human Systems Integration issues in procurement, the original review has been revised. Conclusions are drawn and recommendations made with respect to: 1) the need to plan for human factors evaluations; 2) common design deficiencies; 3) the limitations of human factors engineering techniques and need for further research, and; 4) the need to address human factors issues in Statements of Requirements (SORs) for new systems and equipment.

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